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PANEL ON FIRE RESEARCH AND SAFETY
MARCH 1-7, 2000**

VOLUME 1

Sheilda L. Bryner, Editor



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OVERVIEW OF RESEARCH ON PEOPLE AND FIRE IN THE U.S.

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ABSTRACT

Research on people and fire in the U.S. has recently emphasized practical application over new research. Work continues on several types of evacuation models, but their use in engineering analysis lags behind the state of the art. There is little new modeling or data work in the field of toxicity and other fire effects on people. International efforts to write standards for fire hazard assessment, however, have resulted in much controversy over such details as societal safety objectives and the reasonableness of alternative assumptions, at the fringes of what is known, regarding fire effects on people. These controversies may lead to important new research but for now are being debated with considerable use of non-peer-reviewed data.

INTRODUCTION

Since the last UJNR meeting, research and related work in the U.S. on topics of people and fire have tended to emphasize issues in the practical application and standardization of knowledge gained in prior decades. Both the field of people's reaction to fire (i.e., human behavior) and the field of fire effects on people (e.g., toxicity) also have shown an increasing globalization, with a high degree of international collaborative work and international debate over best ways to interpret and apply past research.

This emphasis on issues of practical application has had a side effect of moving much of the current and recent research from conventional outlets such as peer-reviewed journals and conferences to more advocacy-oriented forums, such as private communications in support of recommended actions on standards. This shift becomes troublesome if it becomes clear that important issues have not yet been settled and fully resolved in the peer-reviewed scientific literature. Such has been the case in recent years for the toxicity issue.

EVACUATION MODELING AND OTHER HUMAN BEHAVIOR

There continue to be three principal types of evacuation models in use and in development in the U.S. and around the world. The oldest type is an optimization type model, which is used to calculate the most efficient paths of escape and thus the shortest evacuation times achievable. This approach, which used to be dominant, has now almost disappeared. In recent work, the only U.S. example identified is by Kostreva and Lancaster [1]. Their multi-objective dynamic programming model has the same advantages and disadvantages as other models of this type. It can be useful to know the

best achievable time but principally as a basis for evaluating more realistic predicted times. This model cannot itself provide realistic predicted times. It can be useful for building design and exiting guidelines to identify efficient escape paths that are not obvious. However, the actual modeling of evacuation behavior remains.

The second type of evacuation model is a node-and-network approach, in which all knowledge and data regarding human exiting behavior is channeled into a small number of variables that dictate exiting choices and speeds of movement along the network. This approach describes actual behavior rather than ideal behavior and is flexible enough to be improved when better data or better understanding of underlying human behavior becomes available. A recent paper within this approach is by Rita Fahy, describing improvements to her model EXIT89 [2]. Ms. Fahy also will present recent work in this area at greater length later in this UJNR symposium.

The third type of evacuation model is a fine structure simulation, which compares to the simpler node-and-network approach as a computational fluid dynamics model of fire development compares to a simpler zone model. That is, the underlying logic of the two approaches is essentially the same, but the much finer structure of the simulation approach creates a model so different in scale that it may be considered different in kind. Rather than a network built on a relatively small number of nodes, each representing a sizeable space, the fine structure simulations use a grid representation. The best known of these simulations are outside the U.S., but one such approach was developed by Feinberg and Johnson, two sociologists at the University of Cincinnati [3]. While the fine structure of the simulation approach appears to offer a more precise model of behavior, at present the lack of proven behavioral models and relevant data forces all the simulation approaches into extensive use of heuristic methods, empirically inferred relationships, and subjectively estimated data. The theoretical advantages of the modeling framework in the simulation approach, therefore, are today more than fully offset by unanswerable questions about the modeling components and the input data.

A common weak point for all current evacuation models is data and knowledge regarding human behavior other than movement toward an exit, where only distance, ability to move, congestion, the building layout, and other such straightforward, observable phenomena are involved. In just the past couple years, Bryan [4] provided a summary overview of the history of the field of human behavior in the face of fire, and his closing remarks pointed to the need to revisit certain commonly used but questionable assumptions, such as the assumptions implicit in using exit drill behavior and speeds, unmodified, to model exiting behavior and speed under real fire conditions. Ozel [5] studied the effect of stress and time pressures on decision-making for evacuation. Lynch [6] studied olfactory response to combustion products as a stimulus that may provide first indication of fire. His experimental results confirmed the view embedded in current safety advice that olfactory response will only rarely arouse a sleeping person. And in two papers, Groner [7,8] continued to refine and advance his view that evacuating people

must be modeled as purposeful decision-makers rather than ballistic objects or rule-bound robots.

Except for Lynch, these researchers provided more questions than answers and stopped short of providing any new data or mathematical relationships that could be used to improve modeling of evacuation. Researchers in Canada and Northern Ireland, and to a lesser extent Australia, have done more than those in the U.S. to develop and disseminate new data. However, the net effect of current work has been a proliferation of new variables whose values must often be determined subjectively and whose relationships to other variables can only be empirically determined by fitting to a generic multi-factor statistical model.

A fundamentals-based set of primary equations – what one might call the Newton’s Law of human behavior – has so far remained elusive, and only recently have there been even fitful indications that some key researchers see the need to look for such equations. This has not prevented the current models from demonstrating an ability to provide useful answers and to accurately predict evacuation times in a wide range of drills and reconstructed fire situations. The models pass the test of what constitutes science; they are subject to disproof by empirical data, and when tested against such data, they provide good predictions.

Also, current practice in the field of fire safety engineering has made very little use of the models that already exist. An engineering analysis by Crowley [9] is a rare published example of the common pattern that engineers either ignore evacuation entirely or model it based on distance and speed only, using readily available speeds for typical occupants. These analyses ignore congestion, variations in human abilities including the special problems of the disabled, and, most importantly, pre-movement times, which are frequently larger components of total evacuation times than the times required for movement.

Fahy and Sapochetti [10,11] issued strongly worded calls to engineers to do better and to recognize the dangers of current practice. The simplified approach to evacuation will tend to understate, often greatly, the time required for evacuation, which means the time during which occupants are exposed to fire effects is also understated. The resulting analysis is not safely conservative or even a prediction on the averages; it is optimistic, which is not an acceptable basis for fire-safe design. Meacham [12] has also provided ideas and approaches on how human behavior factors can be better integrated into engineering analysis.

Some papers on people and fire do not fit neatly into a focus on evacuation behavior. Waters [13] analyzed all the time components from ignition to effective fire suppression. His purpose was to demonstrate that, despite the fact that this objective is often at the center of fire service planning for staffing and company deployment, fire brigades cannot expect to arrive before flashover occurs at a structure fire. Even if travel time can be

reduced to zero, other time components will make that objective unachievable in many, perhaps most, structure fires with flashover potential. This finding indirectly affects work on evacuation modeling, because it removes one of the rationales by which analysts have sometimes sought to minimize the importance of evacuation time in fire safety planning. If early control of fire by the public fire service cannot be reliably, let alone affordably, achieved, then on-site protection and protocols must be sufficient to achieve safety objectives.

Beller and Watts [14] provided ideas on the use of current knowledge regarding human capability and behavior, focusing on observable conditions, to develop improved occupancy classifications for use in building and fire codes. These classifications are used now to simplify the matching of fire protection to the occupants' levels of need. So long as such classifications remain necessary – which means so long as unconstrained performance-based design remains a rarity – ideas like Beller's and Watts' will be useful to improve practice. Jennings [15] provided a literature review of decades of studies of the link between socioeconomic characteristics and fire risk.

FIRE EFFECTS ON PEOPLE

Babrauskas et al. [16] published an overview of the Fractional Effective Dose (FED) approach to the assessment of fire effects on people, using the additive N-gas modeling structure, in which the effects of different combustion products are assessed individually, using threshold dose values in comparison to cumulative doses for individuals. Hartzell [17] provided a summary of the International Standardization Organization (ISO) draft protocol for assessment of toxic hazard, which is a particular application of the FED approach.

In keeping with the content of these two papers, most recent U.S. work in the area of fire effects on people has not been designed to provide new data or new mathematical relationships for modeling. (The Babrauskas reference provided a comprehensive description and rationale of a procedure that had already been described in more fragmentary terms in the literature and used for analysis for a number of years.) Instead, the research has been designed to address the key assumptions in the ISO approach, including many assumptions that are either unsubstantiated or actually counter to the best evidence in the U.S. research literature.

Among the key assumptions, captured in Hartzell's article, are these: (a) Basic FED approaches use thresholds that will injure or kill half the population (which is true), and a large multiplicative safety margin is required to adjust the threshold to protect an acceptably large fraction of the population (which is controversial). (b) Basic FED approaches use thresholds based on animal experiments (which is true), and a substantial multiplicative safety margin is required for inter-species conversion (which is controversial). (c) The toxic hazard of a burnable item is best measured by the combustion products it generates rather than the harmful environment it delivers to the

locations where potentially exposed occupants may be located. This overlooks the mitigating effects of transport, which are especially important in the U.S., where most fatal fire victims are located in a different room than the room of fire origin. (d) Safety objectives are or should be not simply to prevent death but to prevent incapacitation that could lead to death and to prevent any other significant acute or chronic health effects. This objective is far more ambitious than the goals stated in typical building and fire codes, the assumed close link between incapacitation and death is at best unproven and controversial, and the current state of knowledge regarding thresholds for sub-lethal effects has more gaps than proven values.

A particular issue within the larger context is the proposition that post-flashover fire situations are the dominant scenarios of concern and that carbon monoxide is so dominant in these situations that no other fire effects need be considered in predicting and assessing fire hazard. Hirschler [18] provided an extended discussion of the literature in support of this notion, with emphasis on the primacy of post-flashover fires. Nelson [19] provided an analysis of carbon monoxide as a lethal fire effect that also provides some support for this proposition.

As we meet at UJNR, efforts are underway to sponsor significant new research in the U.S. on sub-lethal effects. The ISO approach relies principally on claims made by researchers in the United Kingdom, including a heavy reliance on work that has not been submitted to peer review. Because of the time pressures involved in debating and voting on draft international standards, much of the recent U.S. work designed to respond to the U.K. data has itself bypassed the peer review process, at least for now. This is an unfortunate trend, as it jeopardizes our ability to use proven science and data that have the support of the full scientific community as the principal basis for the writing of codes and standards.

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